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ABSTRACT

This paper reports on a case study that explored the process K-4 educators encounter as they attempted to implement recommendations from the National Council of Teachers of Mathematics (NCTM) Standards. The primary research questions of the study asked: what triggers major school change? what complexities surround school change? and what sustains the reform process and allows/encourages it to evolve? Data sources for the study included transcripts of audio-tapes from long interviews and followup interviews of key informants, field notes of university researchers, and related documents. Results show that initial changes in implementing the standards were mechanical--the lessons and materials did little to change teachers' existing beliefs and practices about mathematics. However, the reform took a different direction when some K-4 teachers "reinvented" mathematics instruction around key ideas and processes within a relevant context for children. Tensions emerged as some teachers' instructional practices began to look different from those of other classrooms, and teachers began to write lessons to supplement the district curriculum. Chaotic situations challenged conventional leadership strategies, interrupted stability of the school climate, and suggested an uncertain future. The reform seemed to depend on educators who believed in the need to restructure and reculture schools. (Contains 36 references.) (RJM)

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Complexity of School Reform: Order and Chaos

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HEADING: Complexity of School Reform

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Complexity of School Reform: Order and Chaos

Reform is a task whose complexity should not be underestimated (Secada, 1992, p. 404).

This case study explores the process K-4 educators encounter as they attempt to implement the recommendations from the National Council of Teachers of Mathematics (NCTM) *Standards* (1989, 1991, 1995). The NCTM documents propose wide-ranging, radical changes in mathematics learning and teaching that are grounded in constructivist theory. To understand the impact of constructivism on mathematics instruction, it is necessary to describe how constructivism differs from behavioristic practices that dominate current mathematics classrooms. Constructivist theory and practice includes several elements beyond the theory and practices of behaviorism. It is not always a simple replacement of traditional "feed-in, feed-out," "question-and-answer" teaching. Instead, constuctivist teaching in mathematics envisions a need for students to know basic skills in context and their need to understand and apply key mathematical ideas. The constructivist teaching/learning environment attempts to develop knowledge and understanding through communication, modeling and reasoning.

Many of the intricacies of this type of school/instructional reform remain unknown. Little is known about how educators experience and lead complex change in an organizational cultural which has historically resisted and hindered major reform (Dewey, 1933; Fullan, 1993; Giroux, 1981; Goodlad, 1990; Grundy, 1987). Less is known about how educators implement an epistemological shift contrary to the current organizational culture. Given the diversity and complexity of teachers' belief systems, it remains unclear how a reform agenda impacts organizational change in school. Therefore, the primary research questions of this investigation are: (1) What triggers major school change? (2) What complexities surround school change? (3) What sustains the reform process and allows/encourages it to evolve?

Theoretical and Philosophical Assumptions

The theoretical and philosophical assumptions of this study are grounded in autopoiesis systems theory (Maturana, 1980, 1981, 1988) and emergent perspective (Cobb& Yackel, 1996). Maturana defines autopoiesis as a self-producing, self-organizing, self-sustaining entity. According to Maturana, a living system is organizationally closed because it has its own identity, its own individuality. A living system is

structurally determined. It is a self-organizing entity. Maturana also argues that an autopoiesis system is an interactively open system where, through the process of interaction and communication with its environment, called "historical structural coupling," the system regenerates itself (Mingers, 1995).

Autopoiesis theory posits that a living system must be understood through the process of the system's interaction with its environment. An interactively open system cannot be studied in isolation, it must be studied through the process of ""structural coupling" (Manturana, 1988). "Structural coupling," means the reflexive relationships between the system and its local situation, the cultural/historical condition (Hatch & Gardner, 1993) and other systems, to include individuals and events. The social context does not and cannot determine the change but triggers or perturbs the changing process emerging through each person. The changing nature of this emergence is inherently an autonomous process and comes from within the individual (Fleener & Pourdavood, 1997; Hargreaves, 1997). Autopoiesis is consistent with emergent perspective. According to emergent perspective, knowing and learning is constantly evolving and is constructed by the individual within the social and cultural condition. "Learning is a constructive process that occurs while participating in and contributing to the practices of the local community (Cobb & Yackel, 1996, p. 185). Autopoiesis theory and emergent perspective play a guiding role for the researchers to understand the dynamic nature of the complex interplay of instructional reform on school change and the emergence of instructional leadership.

Research Design and Methodology

Qualitative research methodology used for this study is guided by constructivist inquiry as explained by Guba and Lincoln (1994). The methodology is consistent with the theoretical framework of this study and is opposed to a positivistic approach to inquiry. Guba and Lincoln(1994) point out that constuctivist inquiry views ontology, epistemology and methodology in a philosophically different way than positivist inquiry.

Ontological and epistemological differences between positivists and constructivists also exist in instructional and curricular designs proposed by reform documents about mathematics learning. These reformed aspects of curricula and instruction are post-modern perspectives that connect more closely with constructivist theory which views teaching and learning as an emerging, exploratory experience that often

lacks linearity, predictability and cause-effect relationships. Doll (1993) suggests that modern curricular and instructional theory is based upon mechanistic causality, a false principle that constrains and closes curricula and leads to teaching and learning practices that lack some bases in reality. According to Doll, post-modern curricular and instructional designs create an open system that focuses on main ideas and skills learned in an authentic problem-solving environment.

Overall, the methodology selected by the researchers attempts to investigate the dynamics of school change within the assumption "that the issue at hand turns in some way on the ways in which individuals conceive of or construe their world" (McCracken, 1988, p. 59.). This construction is multiple, dynamic, and mental (Lincoln & Guba, 1985; Guba & Lincoln, 1989, 1994).

Data Sources

Data sources of this study include: (1) transcripts of audio-tapes from long interviews of key informants, (2) transcripts of audio-tapes from mathematics classroom activities and interactions, (3) field notes of university researcher, (4) related documents (e.g. participant's dissertation, grants, teacher-designed instruction and assessment activities, teacher-parent newsletters, school newspaper, student mathematics portfolios, memos, weekly schedules, etc.) and (5) follow-up interviews with key informants.

Data Collection and Story Analysis

Data collection consisted of two phases: 1) preliminary phase and 2) the active phase. The preliminary phase of this study began June 16, 1997 and ended September 6, 1997. The purpose of this phase was to establish a research framework and to discuss and decide the following issues: (1) defining the research questions, (2) establishing a timeline for research activities, (3) targeting potential interview candidates, (4) clarifying the roles of the case study team members and (5) defining the research study as "research as development" where the case study team, who were active participants in the reform, were also the authors of the case study.

The active phase of the data collection process began September 15, 1997 and continued through December 15, 1998. It included classroom observations, long interviews, group discussions with teacher leaders, related documents, and field notes of parent-teacher-student conferences. All classroom observations and one-on-one interviews were audio-taped and transcribed. Transcriptions were edited by

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the interviewees for clarification and modification. Key informants' transcripts were read by the case study team. Transcripts of other participants were read by the university researcher in order to comply with issues concerning confidentiality.

Data collection and story analysis occurred simultaneously during the course of the study. Based on the emerging patterns and themes, several categories were developed to describe the complexity of mathematics reform and school change.

Emergence of Tensions Created by an Epistemological Shift

Educators at this school live in an environment where principals (principal and assistant principal) rejected modern/traditional teaching, learning, curricular, and assessment practices for mathematics instruction. These principals encouraged an epistemological shift for K-4 teachers, a shift in epistemology about learning that implied major reculturing and restructuring of an elementary school.

Encouraging these reforms brought about turmoil and perturbation from which tensions emerged and deepened. The following events describe the dynamic and evolving nature of tensions provoked by events and initiatives implemented by educators in this school community. Despite a description of chronological events, there is no linearity to the reform process. The reform was chaotic, uncertain, non-linear and indeterminate. It continues to emerge as a self-organizing, regenerative process.

Cosmetic changes: Business as Usual

Initial changes were mechanical; adapting new materials and exploring new content areas such as pattern, probability, etc. A team of senior teachers wrote lessons to integrate mathematics manipulatives into classrooms. The lessons and materials did little to change teachers' existing beliefs and practices about mathematics. Over time, teachers had seen an endless array of new materials, curricula and instructional practices serpentine through classrooms. "You know, this is nothing new. We've done the 'hands-on' gig before" (conversation between a teacher and assistant principal). Teachers were accustomed to scripted lessons and prescribed materials. The new approaches and materials did not perturb the existing culture and structure of the school. Nor did it imbalance the traditional roles and relationships. However, "minor" problems emerged during these cosmetic changes.

> The kids won't let me put away the math materials. My lesson has gone for over sixty minutes. They really like math! They cheer when I tell them it is time for math. But what am I supposed to do about all the other subjects? (conversation between a teacher and assistant principal)

Whereas teachers did not question the nature of imposed instructional changes given to them by senior teachers, they did question the issue of time for other instructions.

The reform took a different direction when some K-4 teachers, in collaboration with secondary mathematics and university educators, "reinvented" mathematics instruction around key ideas and processes within a relevant context for children. The restructured, "streamlined" mathematics curriculum focused on big mathematical ideas like: *unit, unitized systems, zero to infinity, change, chance, dimensionality, location* and key mathematical processes like *combining, comparing* and *partitioning*. "When I leave this building, I feel better than when I came in" (secondary mathematics teacher/teacher-leader in the reform). Focusing on main ideas was seen by some teachers as unusual since this curricular design lacked a focus on numerous, specific behavioral objectives that dominated the school district's mathematics curriculum. The "new" curricular design was more connected to Bruner's idea of recursive learning (1960, 1986) and Doll's idea of a post-modern, emergent curriculum (1993) based on spontaneous generation that would "allow the human power of creative organization and reorganization to be operative" (1993, p.117).

Tensions emerged as some teachers' instructional practices began to look different from other classrooms and teachers began to write lessons to supplement the district curriculum. Many teachers were unfamiliar with instruction that was emergent, flexible, and responsive to student voices. Teachers were also unfamiliar with mathematics instruction that was based on reasoning, problem-solving, communication and mathematical representations. "When this reform started, I did not agree with it because I did not understand it. I had to have a conversion. I had to come to a place to understand it" (teacher-leader).

As the reform evolved, many educators struggled to make mathematics relevant to students' experience. Some educators disgarded their dependency on mathematics textbooks, wrote instruction and

designed a performance task assessment system to monitor student growth over five years. What emerged within this collaborative structure was a different pedagogy based on constructivist practice.

Several events were happening simultaneously that also created disequilibrium. A new mathematics textbook was adopted at the district level. Teachers at this school recommended to the principal that the new textbook should not be ordered for the school. "Don't order math textbooks. We write lessons better than that." (teacher-leader). The principal followed this recommendation. His decision was questioned by district administrators and some senior teachers. Not giving books to every student made some educators question the credibility of the reform.

Epistemological shift: Business as Unusual

Tensions began when school principals encouraged and valued *individual* teacher's efforts to design different instructional models and learning environments through action-research proposals. Action-research proposals were funded and supported with grant money. Teachers ordered materials and equipment necessary to develop their instructional models. A few senior teachers who previously had been active participants in the reform, refused to submit proposals. "I'm not going to have *my* instructional model judged by anyone. No one is going to tell *me* whether I have met my goals or not." (teacher). Most teachers who refused to submit proposals, distanced themselves from the reform process and thus limited opportunities to communicate their ideas and opposing views about instructional change.

When some participants built and implemented new models, they recognized incompatibility between the existing views of mathematics teaching and learning and their emerging constructivist perspective. Instead of "repairing" and "altering" mathematics curriculum and instruction, the models suggested a different vision of mathematics.

Classrooms and instructional practices began to look different as constructivist theory was embraced by some teachers and the principals. Tension began to escalate over the kinds of mathematical problems that were designed for kindergarten and first grade students. Some teachers complained that mathematics problem-solving was too difficult for young children. A few teachers were openly critical of what they called "developmentally inappropriate" lessons and instructional practices. They claimed the problem-solving experiences were "too complex" (dividing, multiplying, use of fractions) for 5 and 6 year

old children. The principals responded to their "developmentally inappropriate" claims by citing research about young children's inventive minds, and suggesting that the existing curricula may *really* be "developmentally limited."

As mathematics looked more "unmathlike" in individual classrooms, students, parents and the principals responded favorably. People noticed that young children enjoyed the rigors of complex problem-solving. Children were relating well to mathematics within the context of *their* everyday experiences and solving problems that normally would not be introduced for several years. Students used multiple strategies to solve problems such as: adult role playing, building concrete models, illustrating and dialoguing about strategies and solutions.

Some non-participants saw little value in mathematics dialogues and problem-solving with young children. "These little kids shouldn't be sitting so long on the floor talking about math with the teacher. They should be actively touching and building things themselves. They can't sit still for over ten minutes" (conversation between a teacher and principal).

Despite the complaint about mathematical dialogues with young children, some teachers continued to refine dialogues and value them as a key component for building mathematical understandings. Teachers connected the mathematical dialogues to student problem-solving mathematics journals where students colorfully illustrated, wrote and calculated their solutions. Parents and outside educators/researchers were impressed by the degree of sophistication young children demonstrated in these mathematics journals. This perception from outside educators and parents sparked personal resentment and jealousy from some dissenting teachers who attacked the principal's decision-making style in an effort to stifle reform.

Criticism and tension began to be accepted as a "normal" occurrence. The principals refused to allow tension and criticism to discourage or stop participants. They determined that "business as unusual" could coexist with "business as usual." They ceased trying to "convert" non-participants and instead decided that everyone did not have to participate. Some non-participation did not preclude individual teachers from developing effective reformed practices. Allowing the coexistence of two seemingly opposing views/culture created constant dissonance in the school where teachers were often

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reminded how much they were changing. "I don't want to be like them (non-participants). I'm really different now. I like this change! How can I make sure that you don't see me as thinking what they do?" (conversation between a teacher and assistant principal). This dissonance may be responsible for nurturing the synergy that surrounds the reform and keeps the reform moving forward.

> We let people make choices about how to implement change. Some took the challenge, others did not. I think, though, people were surprised that we pulled the train out of the station without everyone on board. But the reality was that if we waited, like we used to do, for everyone to be 'on board,' we still would be at the station. They were surprised we could go on without them. I think they were also surprised at how fast and far the train went. I guess all of this was most unusual and disruptive to some. I didn't think about it at the time. We were given grant money to do this, and the reform was interesting and exciting! (assistant Principal)

Non-participants' objections to the reform seemed to focus more on the personal and socio-political atmosphere of the school than on the theory and practices within the reform. Often, non-participation seemed to be beyond intellectual and philosophical differences and more focused on changes in rules, roles and relationships such as not treating everyone the same, not requiring all teachers to "be on the same page," not requiring sole reliance on district curriculum, allowing teachers to make choices, encouraging experimentation, celebrating the creation of different learning environments, validating risk-taking and promoting research and intellectualism. All this was not "business as usual." Tension seemed to escalate as participants deliberately moved forward despite criticism and resentment from some non-participants.

The principals were criticized for discriminating between "haves" (participants in the reform) and "have nots" (non-participants). Their decisions were viewed by some non-participants as creating an elite group in the school. This was contrary to the conventional notion of school as "happy family." The principals were aware of the factious nature of these decisions and the potential risks.

> They do want to change behavior and instructional practices and to me that gets to be a challenge. The school will have to learn to find ways to start to work with people and certainly they have done that to a certain extent. However, they need to make everybody feel they have

something to contribute so that the teachers begin to change their instructional practices. Therefore, it is something internal, something that motivates them and not that they feel it is dictated by the organization. That makes a difference. (district administrator)

About 75% of classroom teachers supported the reform process and worked toward designing instruction, curricula, and assessments according to constructivist theory. A critical group of 12 supportive teacher-leaders included 6 new, non-tenured teachers who are guided and mentored by the more senior teacher-leaders. It is the recognition of this teacher leadership group that upset the social and political environment within the school building. Some senior, tenured teachers resented not being selected by principals to be "teacher-leaders." They felt excluded from the instructional reform even though all teachers were invited to professional development sessions about mathematics led by teacher-leaders.

Teacher-leaders emerged as change agents for the reform. Teacher-leaders assumed the role of: decision-makers, adult learners, designers, mentors, staff developers, instructional leaders and action-researchers. To some teachers the selection of teacher-leaders and the teacher-leadership role was thought to be unconventional. Traditionally, leadership in education has been vested mainly in the principal-administrator position. Principals who encouraged, granted and depended on leadership from teachers may be creating cultural disequilibrium, especially when the purpose of teacher leadership was to create an epistemological/paradigmatic shift in mathematics instruction and curricula.

Some non-participants complained to union leaders, district administrators and the principals about the divisiveness of the reform and low morale among some senior teachers who felt ignored and excluded from leadership opportunities. "You guys better spend some time healing your building" (district administrator to assistant principal). These actions seemed to imply that some people saw conflict as destructive and wanted a return to "business as usual."

I feel I need to do something to help improve the morale around here. We all used to be so happy--laughing in the halls, doing things after school, having fun at staff parties. We're not all like that anymore and it's sad. We need to do something to bring everyone together. (conversation between a teacher and assistant principal).

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> I believe everyone has a special gift to do something. No matter what it is, that special gift needs to be recognized here at school. (conversation between a teacher and assistant principal)

The loss of "happy family" was also regretted by some teacher-leaders. Principals tried to make teacher-leaders understand that paradigmatic changes usually occurred in an atmosphere of disequilibrium, ambiguity and tension. Principals believed a *transforming* school depended on disturbance to the established equilibrium and therefore, accepted the fact that the course of change would not be smooth.

Some teacher-leaders did not agree that the school suffered from low morale. They met with a district administrator to explain and defend the reform process, and the principals' decisions about instructional reform. Teacher-leaders began to realize that major instructional reform involved political tension and maneuvering.

Emergence of Critical Mass

Teachers as action researchers and writers evolved in different ways. Teachers sought new ways and materials to improve classroom instruction. They wrote grants and lobbied principals for additional school funds. Teachers were expected to share the results of their action-research projects with other staff members. Their instructional practices were replicated by other teachers. These action researchers became teacher-leaders.

Teacher as instructional designer was fundamental to professional development and adult learning. As the reform evolved, it became clear that teachers reflected on what they knew about mathematics and connected it to how children learn mathematics. Teachers writing instruction had a significant impact on staff development programs. In-service programs were designed to expand teacher content knowledge and pedagogy. Secondary mathematics teachers worked closely with principals and teacher-leaders to design staff development meetings that helped teachers write instruction.

Structures were created to inform parents about changes in mathematics teaching. Parent-Teacher Math Nights were designed and led by teacher-leaders and principals. These meetings communicated the reform to parents. During these meetings, parents actively engaged in building models, drawing and writing about mathematics. Through these activities, parents began to see the

differences between traditional and constructivist mathematics teaching and learning. These meetings also suggested how parents might support and facilitate student learning at home.

Ongoing communication about pedagogy also emerged from the reform efforts. Teachers began dialoguing about changing instruction and learning environments to accommodate a different teaching/learning theory. When teachers asked different types of questions, valuing student experiences, and supporting student risk taking; they saw differences between what they taught and what students learned. This provoked individual teacher change. "Its hard to change people's minds. You couldn't change mine. It just so happened in my own pursuit, my own reason. I came upon it and changed my mind" (teacher-leader).

The reform began to break down the walls of isolation among teachers. Teacher-leaders discussed instruction and student work with each other and secondary and university mathematics educators. Collegial relationships and professional discussions encouraged many teachers to take risks and learn mathematics (Pourdavood & Fleener, 1998). Collaborations and common interests among teacher-leaders seemed to encourage the development of a professional school community where trust, professional respect and pride in students' abilities to do significant mathematics was valued.

Fragility within Chaos and Order

Radical educational reform abounds with complexity (Fullan, 1997; Hargreaves, 1997).

School leaders may expect complexities when implementing NCTM Standards (1989). The Standards challenge school leaders to alter/rebuild existing educational cultures and structures to implement NCTM reforms. Creating an epistemological change in learning and teaching may expose weaknesses and flaws in current educational practices. Epistemological changes perturb existing education systems and create conflict because a "business as usual" mentality reacts to cultural/structural changes.

> ... disturbances of an established equilibrium are key to the equilibration process; they are the stimulus or burr that excites organisms to reshape themselves. However, the environment does not shape the organism, organisms shape themselves ... organisms (including humans) make 'positive reactions' to environmental pressures. (Doll, 1993, p. 81)

Tensions and conflicts may provide school leaders opportunities to better understand the nature of change and develop strategies to lead instructional reforms. A reflexive relationship between status quo and reform may be a source for renewing and sustaining a change.

Instructional reform at this school supports research findings on organizational change. Changes at the school ventured far from equilibrium. Conflict emerged that challenged the value and credibility of the NCTM reforms. For instance, State Proficiency Tests began in the midst of the reform. The Fourth Grade Mathematics Proficiency Test was not congruent with this school's curricular and assessment reforms. However, the school's fourth graders scored about the same as fourth graders at four other elementary schools in the school district. State level and district educators and the general public expected the school's Mathematics Proficiency Test scores to be higher. "We are so excited about your mathematics project. It is truly remarkable. However, politically your Proficiency scores hurt you. And your credibility suffers" (conversation between a department of education official and assistant principal).

Moreover, mathematics reform at this school represented an epistemological change. Teacher-leaders moved away from behaviorist dominated instruction toward teaching and learning practices that reflected constructivism. This represented a paradigmatic shift for teacher-leaders and principals because it transformed classroom settings, communication with parents, teacher interactions, leadership roles, instructional/assessment practices and the role of student voices in mathematics classrooms.

The change process was also chaotic. Chaotic situations challenged conventional leadership strategies, interrupted stability of the school climate, and suggested an uncertain future. Chaos and uncertainty forged new leadership strategies to value the creation of new roles and relationships dependent upon teachers as writers and risk-takers. Principals focused on preparing teacher-leaders for an unknowable journey. The reform seemed to depend on teachers and principals who believed in the need to restructure and reculture schools, and who were willing to take risks and spend the time necessary to do it. Furthermore, students seemed to play an important role. Student voices and experiences acted as catalysts for teacher development (Pourdavood & Fleener, 1997). Students and teachers constructed mathematical understandings together.

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Within all these complexities there may be good news for fundamental changes in instruction, organization, and professional development. It is not unusual for good news to emerge from within a climate of constant conflict and disequilibrium (Fullan, 1997; Pourdavood, 1997; Prigogine, 1997; Senge, 1990; Stacey, 1992; Waldrop, 1992; Wheatley, 1994). However, good news may still depend on the following uncertainties: (1) Can this, or any, instructional reform exist beyond the building level? (2) Will other educators take risks to promote school change? (3) What is the fate of this school community and those individuals who have taken major risks to change traditional beliefs and practices? (3) How will improvement in student understanding be meaningfully evaluated? (5) How can schools be restructured to facilitate and encourage fundamental change? These questions are echoed by many voices in the school community. Doll (1993) expressed similar ideas on organizational change by quoting Maturana and Varela (1980) about an autopoietic system.

> a network of processes of production (transformation and destruction) of components that produces the components that through their interactions and transformations continuously regenerate the network of processes (relations) that produced them. (p. 85).

Doll added that Manturana's and Varela's assertions emphasized that " a system . . . can regenerate itself but, when it does not receive enough perturbations to perform transformations, will disintegrate" (p. 85).

There is hope that school communities like the one for this study will take risks to restructure and recreate themselves. Cowen (1995) reflected on the importance of Papert's (1993) notion of megachange in education occurring in little schools:

> Megachange in education may only occur through a grass-roots approach, the emergence of little schools' where teachers, parents and children explore and create new learning situations ... networking among these schools would prevent isolation and elitism and provide an opportunity to select successful changes. (p.47)

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